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BMNR 344
1421 √

NOT FOR PUBLICATION

AN EXPERIMENT IN BIOLOGICAL CONTROL OF THE BALSAM WOOLLY APHID IN NORTHWESTERN UNITED STATES

by

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(A paper for presentation at the 12th International Congress of Entomology at London, England, July 8-16, 1964)

INTRODUCTION

It is appropriate that biological control be discussed at an International Congress. Probably no entomological activity is more international in character. Our efforts to control the balsam woolly aphid in the northwestern United States by importing and colonizing insect predators is an example. We have received predators from seven countries through the cooperation of an international organization, several government agencies, and numerous individuals.

In 1956, at the International Congress of Entomology in Montreal, Canada, the early phases of the biological control program in North America against the balsam woolly aphid were discussed by several entomologists. Papers were presented which described the aphid problem, the number and kind of predators found in Europe, and preliminary results of liberations in eastern North America. My paper concerns a biological control program against the aphid in the states of Oregon and Washington that began shortly after the Montreal Congress; it has now been in progress 7 years. I will briefly describe the woolly aphid problem in our area, chronicle the cooperation received, evaluate the accomplishments, and speculate on prospects for the future.

For orientation, I will briefly discuss the host insect and show a few color slides of it and the damage caused.

The balsam woolly aphid is a completely parthenogenetic homopteran which confines its activities to trees in the genus Abies, the true firs. In different countries, the woolly aphid is variously assigned to the families, Adelgidae, Chermidae, Chermesidae, and Phylloxeridae and is known as Adelges piceae, Chermes piceae, and Dreyfusia piceae.

The balsam woolly aphid is native to Europe, infesting Abies alba and A. nordmanniana. According to the literature, it is not considered a serious forest pest in its native environment. It was introduced into eastern North America around 1900, presumably on nursery stock. It was found on the west coast of the American continent in 1928.

In the northwestern United States the woolly aphid is destructive to subalpine fir (Abies lasiocarpa), Pacific silver fir, (A. amabilis) and grand fir (A. grandis). The current outbreak was discovered in 1954 when widespread killing was noted in high-value forests in the mountains of Oregon and Washington. By 1957, the infested area covered some 600,000 acres. (Slide of Pacific silver fir stand along logging road; loaded log truck in foreground and Mount St. Helens in background). The currently infested areas has declined somewhat since 1957, but several billion board feet of saw-timber size trees in stands, such as you see here, have been killed or seriously weakened. Severe damage continues on important timber, watershed, and recreation areas. (Slide of killing around Twin Lakes Meadow, Umpqua N.F.). This slide shows killing of subalpine fir around an alpine meadow in Oregon. (Slide of Twin Lakes Meadow with lake in foreground--picture taken from an over-look). This slide gives a better perspective of this recreational area.

The balsam woolly aphid feeds exclusively in bark parenchyma on the twigs, limbs, or main stem of the host tree. (Slide of single aphid). This is a single adult feeding on a branch; the amber-colored objects are eggs which are usually obscured by the waxy secretion you see being produced by the aphid. (Slide showing ventral view of adult balsam woolly aphid which was cleared and mounted on a microscope slide). This is a micrograph of an adult aphid, cleared and mounted; the long thread-like structure is the organ through which the aphid feeds. When the aphid feeds, it introduces a substance into the cortex which produces a reaction in the vascular cambium and differentiating tissues.

(Slide showing example of gouting). Infestation on the branches cause abnormal swelling "gouting", at the nodes and kill or inhibit the buds, thus inhibiting or preventing new growth. As old needles drop, the crown becomes increasingly sparse; after many years of repeated gouting the tree dies or lingers in a state of near death. Even a small population may cause gouting and death. (Slide of stem attack). Mass infestations on the main stem, an example of which you see here, are usually more serious. The sieve cells and phloem parenchyma, which function vitally in food transportation and storage, are materially altered in form and position; also, the tree is induced to produce annual rings of abnormally dense wood--wood which appears to place considerable stress on the tree's water-conducting system. A tree with a heavy stem infestation may be killed within 3 to 4 years.

NATIVE PREDATORS

Shortly after discovery of the balsam woolly aphid outbreak in Oregon and Washington, it was decided that biological control was the only promising method available. One of the first steps to evolve in the program was to catalog and evaluate the native predators that attack the aphid or its near relatives.

One group of 18 species was found to prey upon the woolly aphid. Most were syrphids and chamaemyiids; the others were chrysopids, hemerobiids, itonidids, two beetles and an anthocorid. They were general feeders, found associated with many species of native homopterans as well as the balsam woolly aphid. Populations generally were small, so small that some species were not found every year despite intensive collecting.

Another group of predators was found to prey on native chermids but not on the balsam woolly aphid, even when it was closely associated with the natives. These predators were quite specific and frequently were abundant. In many cases they were closely related taxonomically to predators successfully colonized for control of the balsam woolly aphid.

This review showed that native predators offered little prospect of curbing the woolly aphid, hence that biological control efforts should be concentrated upon importing and colonizing more specific predators.

INTRODUCTION OF PREDATORS

Since 1957, 22 species of insect predators of potential value against the woolly aphid have been imported into the northwestern United States (Table 1, appendix). Eighteen were liberated in the field; four others were tested in the laboratory but not released. The insects came from India, Pakistan, Japan, Australia, Sweden, Germany, and Czechoslovakia. Entomologists of the Forest Service, U. S. Department of Agriculture, were responsible for receiving, liberating, screening, and evaluating these predators. Entomologists of Oregon State University and Weyerhaeuser Company, a large timber owner, cooperated on many occasions.

Most of the predators received during the first 3 years of the program came from Europe. They were provided, gratis, by the then Science Service, Canadian Department of Agriculture. The Canadian Government obtained the predators by contracting with the Commonwealth Institute of Biological Control, presently headquartered in Trinidad, British West Indies, Investigations and collections in Europe were largely accomplished by entomologists working out of the C.I.B.C. laboratory at Delemont, Switzerland. Quarantine services for most of the incoming predators were provided by the Canadian Department of Agriculture Entomology Laboratory at Belleville, Ontario.

Predators received from Europe after 1960 were collected by entomologists of the United States Department of Agriculture, Agricultural Research Service Laboratory at Paris, France. Quarantine services for these predators and those from Asia were provided by the Agricultural Research Service Laboratory at Moorestown, New Jersey.

Many of the predators received in the northwestern United States came from the southern Himalaya Mountains of India and Pakistan. Himalayan predators were investigated and collected by entomologists from Commonwealth Institute of Biological Control Laboratories at Bangalore, India, and Rawalpindi, Pakistan. Services of personnel and equipment at these stations were contracted by the United States Government and were a function of the former International Cooperation Administration, now the Agency for International Development.

RESULTS OF PREDATOR INTRODUCTIONS

Predators liberated in Oregon and Washington have shown varying degrees of success in adapting to the new environment. Five species have become established. A sixth produced progeny, then disappeared. Of the remaining 12 species liberated in the field, none produced progeny, and most failed to survive even a few weeks.

The five established species are two beetles -- Laricobius erichsonii, family Derodontidae, and Pullus impexus, family Coccinellidae; and three flies -- Aphidoletes thompsoni, family Itonididae, and Cremifania nigrocellulata and Leucopis obscura, both family Chamaemyiidae. All were imported from Europe. Their principal host in Europe is the balsam woolly aphid, and they have continued to prey on that host in their new environment. None of the Asian or Australian predators survived.

So far, Laricobius erichsonii, shows most promise of being effective against the woolly aphid in Oregon and Washington. It attacks in large numbers, preys early in the year, and feeds voraciously on the aphid. It has only one generation per year, which lessens its effectiveness and slows its dispersal. Although dispersal was slow in the first few years after release, it increased steadily with time. In one area where the predator has been established for 5 years, the cumulative radius of spread was 75 feet the first year, 850 the second, 1,400 the third, 3,600 the fourth, and 9,600 feet the fifth year. This was in an area where aphid populations were abundant, not requiring diligent searching by the predators. In another area, where aphid-infested trees were not so abundant, the radius of spread was 2,600 feet in 2 years.

Laricobius erichsonii has demonstrated on intensively studied sample trees that it is capable of ~~tree~~ true control -- aphid populations exposed to predation were reduced while unexposed ones increased. Nevertheless, predation by Laricobius always began too late; all study trees died. And herein lies the predator's greatest fault: Developing infestations are not attacked until they reach a population level of at least 10 aphids per square inch of bark. A tree as suceptible as Abies lasiocarpa is usually doomed to die by that time.

Aphidolete thompsoni may prove eventually to be the best predator introduced. It develops large populations, it thrives in a wide variety of environments -- from very wet to very dry, and it will attack light aphid populations. The last factor makes Aphidoletes a good choice for liberation in conjunction with Laricobius.

When Aphidoletes was first liberated, it appeared that it would disperse slowly, but this has not proven to be the case. This predator starts slowly and then speeds up, its two or more generations per year enhancing its potential for spread. A measured dispersal of 8,600 feet in 4 years betters the best 4-year dispersal of Laricobius. A shortcoming of Aphidoletes is that it attacks too late in the season to materially affect the first aphid generation. But this timing may be advantageous because it lessens competition with Laricobius erichsonii.

Techniques have been developed for moving colonies of Laricobius and Aphidoletes from one area to another within the Pacific Northwest. This eliminates the need for further introductions of these species. It also hastens dispersal, and permits better timing of liberations.

Of the remaining three introduced predators, Pullus impexus is the most promising. It has two characteristics much desired in a predator: it attacks very early in the year and will feed at very low prey densities. Even so, this beetle appears to offer little in the way of control. Dispersal is slow, and distribution in the forest extremely erratic. Although the predator readily attacks low prey populations, it seems to prefer old declining populations rather than those just starting.

Cremifania nigrocellulata and Leucopis obscura, have been established 5 years. Both are bivoltine and both have spread well. In 1963, C. nigrocellulata was recovered in an isolated, aphid-infested stand nearly 3 miles from the release point. L. obscura also is a strong flier and has spread rapidly after release. Nevertheless, neither of these species appear promising. They seldom develop large populations, and they frequent, almost exclusively, trees with very heavy aphid populations. These trees nearly always die, so the predators accomplish little.

So far, results from the 5 established species have been discouraging. Aphid populations are generally increasing, and trees continue to die in forests where predators have been established for several years. In one aphid-infested forest, for example, four species of introduced predators have been established for 5 years, yet 55 percent of the trees have died during that period. Less intensive studies and observations in other forests where the predators are established show much the same results.

SUMMARY AND CONCLUSIONS

I would like now to summarize and draw some conclusions from our 7-year experiment in biological control of the balsam woolly aphid. To do this, I will pose four questions, and then attempt to answer them.

1. How successful is the biological control program?

   We must conclude, as of this time, that the introduction of insect predators has failed to achieve acceptable control. In areas where the predators are well established, aphid populations are generally increasing, and trees are continuing to die in great numbers.

2. What are our future plans?

We plan to continue introduction of new predators as they are found in various parts of the world. We will also continue to evaluate establishment, dispersal, and effectiveness of those now established, though our total effort will be somewhat less than in past years. In addition, Laricobius and Aphidoletes will be recolonized from areas in our region where they are already established to areas where they are not.

3. What are the prospects for biological control of the balsam woolly aphid in the Pacific Northwest?

In our opinion, effective control of the balsam woolly aphid with predaceous insects remains promising. There are two main reasons for our continuing optimism. First, exploration and investigation of new candidate predators is being made in various parts of the world. Truly effective predators may yet be found. Second, it seems likely that predators, including those now established, will be more effective in controlling aphids in our managed forests of the future than in the present wild, unmanaged ones. The aphid attacks trees only after they have reached a rather well-defined susceptible age. Currently we have very large forest areas where essentially all the trees are overmature, hence they are mass-attacked and killed over wide areas. In managed forests, which are becoming a reality, relatively few trees will reach aphid-susceptible age at a given time. Also, potentially susceptible trees often will be harvested before becoming infested. Under such conditions, it seems likely that predators will be better able to exert control.

4. What have we learned?

A significant finding from the experiment thus far is that biological control is time consuming, costly, and technically exacting.

We learned much about the details of handling and liberating beneficial insects -- how to rear the species that came to us in immature forms, how to separate parasites from them, how to transport predators long distances to field liberation points, how to properly build and attach cages to trees, how to select the best liberation sites, how to make surveys of establishment and dispersal, how to design studies and equipment for assessing effectiveness. We are convinced that the acquiring and use of such learning is vital in carrying out a biological control program.

We have learned that the success of a biological control program such as ours is inherently dependent on the species of predators selected. In some cases, predator species were liberated that more complete screening in the country of origin could have disqualified thus making project efforts more effective. For introduced species, it is vitally important to have information on synchronization of predator and host, alternate hosts, diapause and hibernation habits, and much other biological data. Such information is also needed for the proper handling and evaluation of those predators selected for introduction.

Last, and perhaps most important, we learned from experience that biological control is uncertain. Despite the best efforts of entomologists exploring worldwide for promising predators, despite excellent international cooperation in shipments to us, and despite our best efforts in handling and releasing the predators, the control objective has not been achieved. Biological control is not yet a panacea for all insect control problems.

Finally, I would like to stress the importance and value of free international communication and cooperation in a biological control effort. We feel the balsam woolly aphid predator program is a good example of entomologists from many countries working toward a common goal. Particularly outstanding in this program has been the opportunity for participating entomologists to get together personally in many parts of the world. We have benefitted greatly in Northwestern United States from the visits of several noted entomologists associated with the balsam woolly aphid program. To these, and all others who have assisted us in this experiment, we extend our gratitude.

Table 1.--Foreign insect predators introduced since 1957 for control of the balsam woolly aphid in Oregon and Washington

Species, order, and family	Source	Years released	Number released
Adalia luteopicta Muls. (Coleoptera: Coccinellidae)	India	60	156
Adalia tetraspilota Wse. (Coleoptera: Coccinellidae)	India Pakistan	59, 60, 61	176
Aphidecta obliterata L. (Coleoptera: Coccinellidae)	Sweden Germany	58, 59, 63	2,217
*Ballia diana (Coleoptera: Coccinellidae)	India	61	100
Ballia eucharis Muls. (Coleoptera: Coccinellidae)	Pakistan	59	85
Chilocorus kuwanae Silv. (Coleoptera: Coccinellidae)	Japan	58	135
Exochomus lituratus Gorh. (Coleoptera: Coccinellidae)	Pakistan	60, 61	98
Exochomus uropygialus Muls. (Coleoptera: Coccinellidae)	Pakistan	59, 60	6,682
Harmonia breiti Mader (Coleoptera: Coccinellidae)	India	59, 60	83
Leis dimidiata F. (Coleoptera: Coccinellidae)	India	59	23
*Oenopia sauseti Muls. (Coleoptera: Coccinellidae)	India	60	46
Pullus impexus Muls. (Coleoptera: Coccinellidae)	Germany	60, 62	1,342
Scymnus pumilio (Wse.) (Coleoptera: Coccinellidae)	Australia	59, 60	2,859
Synharmonia conglobata L. (Coleoptera: Coccinellidae)	India	59, 60	127
Laricobius erichsonii Rosen. (Coleoptera: Derodontidae)	Czechoslovakia Germany	58, 59, 62	12,406
Cremifania nigrocellulata Cz. (Diptera: Chamaemyiidae)	Czechoslovakia Germany	58, 59	1,374
Leucopis obscura (Hal.) (Diptera: Chamaemyiidae)	Maine (Europe)	58, 59	2,785
Leucopis sp. (Diptera: Chamaemyiidae)	Pakistan	59	15
Aphidoletes thompsoni Mohn. (Diptera: Itonididae)	Czechoslovakia Germany	57, 58, 59	34,204
*Chrysopa sp. I (Neuroptera: Chrysopidae)	Pakistan	61	43
Chrysopa sp. II (Neuroptera: Chrysopidae)	India	61	421**
*Undetermined Hemerobiidae (Neuroptera)	India	61	10
	Total predators introduced		65,387

* None liberated in the field; maintained in laboratory rearing.
** Number includes 288 eggs.